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# FOREST PRODUCTS UTILIZATION TECHNICAL REPORT No. 8

## HANDLING, DRYING, AND STORING HEAVY OAK LUMBER

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### Introduction

Oak continues to be in high demand for furniture, trim, molding, and flooring. Oak lumber production has continued at a level of about 3.5 billion board feet a year since 1955. Oak leads all other hardwood species in volume use. Oak is also a principal hardwood species on commercial forest land, and constitutes about 35 percent of the hardwood sawtimber volume.

Use of oak for furniture and trim requires an attractive defect-free appearance; therefore, quality drying is important. Oak is a difficult (refractory) wood to dry, and often surface checking, splitting, honeycomb, or collapse occur if the wood is subjected to a severe drying condition. With the demand for oak species continuing, utilization procurement sources have tapped areas and species of oak previously purposely ignored.

Woodworking and drying characteristics of the oaks vary considerably with species and site. Favorite procurement areas have been the Appalachians and the Northern States. Lowland oaks grown in the South or on wet sites tend to be denser and faster grown than upland oaks grown on Appalachian or northern areas. The generally slower growth and lower density of the upland oaks makes them easier to dry and machine. The following tabulation lists 17 of the principal oak species.

Northern and Upland Oaks

Red oak:

Black (Quercus velutina)
Cherrybark (Q. falcata var. pagodaefolia)1/
Northern red (Q. rubra)
Pin (Q. palustris)
Scarlet (Q. coccinea)
Shumard (Q. shumardii)1/
Southern red (Q. falcata var. falcata)

White oak:

Bur (Q. macropcarpa)
Chestnut (Q. prinus)
Chinkapin (Q. muehlenbergii)
Swamp (Q. bicolor)
White (Q. alba)

Southern Lowland Oaks

Red oak:

Cherrybark (Q. falcata var. pagodaefolia)2/
Laurel (Q. laurifolia)
Shumard (Q. shumardii)2/
Water (Q. nigra)
Willow (Q. phellos)

White oak:

Overcup (Q. lyrata)
Swamp (Q. michauxii)

1/ If grown on upland sites.

2/ If grown on lowland (wet) sites.

The problems associated with handling and drying heavy (thick) oak are multiplied if lowland oaks are used. In the trade, "heavy" generally denotes thick lumber, and will be so used in this report.

The purpose of this report is to suggest methods of optimizing the yield of all oaks by proper handling, drying, and storing, and to conserve energy through modified drying methods, especially in the heavy oaks 6/4 inches and more in thickness.

## Yard Handling Normal Green Material

Heavy oak should be end coated as soon as possible after trimming to length. Commercial preparations are available from most dry kiln manufacturers and a few custom kiln-drying companies. End checking from failure to end coat can result in losses exceeding 5 percent of the board volume.

To be effective, end coatings must be applied while lumber is still green and before end checks begin. In freshly cut lumber, end checks can form in a few hours in hot, windy weather. If some end checking has begun, boards should be trimmed back to fresh, unchecked wood before applying end coating.

Heavy oak should never be placed on an air-drying yard without protection from sun, rain, and wind. An alternative to air drying is drying under controlled conditions in a kiln or a low-temperature dryer. Probably the best air-drying situation for heavy oak is drying under a shed. Shed construction may consist of a simple pole frame with wood truss roof design or a sophisticated metal system (figs. 1, 2). A louvered back wall is also helpful in reducing air circulation (fig. 3).

Minimum protection will be afforded by placing piles of heavy oak with roof covers in the center of a yard to provide shelter from hot, dry winds. Pile covers of wood construction or of metal will keep rain and sun from degrading top courses (figs. 4, 5). This is minimal protection, however, and substantial degrade and volume losses can still occur under these conditions.

Cool, shaded sheds with protection from wind will generally provide the best yard protection. Another perhaps unusual type of protection is to cover all sides of green, roofed piles with burlap. This protects piles from wind and sun and can produce high-quality air-dried material (figs. 6, 7A, B).

## Presurfacing

Research and commercial practice has shown that presurfacing of green lumber removes the tiny fractures on the surface of boards caused by the headsaw.[1/] This blanking, or presurfacing, cleans

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1/ McMillen, J.M. and Baltes, R.H. 1972. New kiln schedule for presurfaced oak lumber. For. Prod. J. 22(5):19-26.

and removes headsaw tear marks and substantially reduces the boards' tendency to surface check. As a result the kiln schedule can frequently be accelerated slightly, thus reducing drying time as well as keeping the lumber free of checks. Side benefits are increased kiln capacities and improved uniform drying with less warp because of the uniform thickness. Wide ranges in moisture content after drying are minimized and equalizing periods shortened. Presurfacing to minimize degrade in drying oak should be seriously considered particularly if reinspection for grading is not involved.

## Handling Bacteria-Infected Material

The heartwood of living trees can become infected with bacteria which produce enzymes capable of weakening wood.[2/] This commonly results in ring shake in the tree, and when cut, the wood emits a rancid odor. During drying under regular mild kiln-drying schedules, this bacteria-weakened wood will degrade and cause honeycomb and ring failure.

Research is underway at the Forest Products Laboratory to find methods of drying infected wood and identifying and isolating bacterially infected material. Thus, infected logs or lumber could be handled separately to minimize drying degrade.

## Low-Temperature Drying

Solar dryers, forced-air dryers, low-temperature kilns, and controlled-air dryers may be used for drying heavy oak if recommended operating procedures are carefully followed.

For green refractory woods, solar dryers should have initial wet-bulb depressions of not more than $5^{\circ}$ F and low dry-bulb temperatures during startup. A working unit designed for drying small quantities of lumber has been in operation for over 10 years[3/] (fig. 8). For a green load, on sunny days the initial dry-bulb temperature seldom exceeds $10^{\circ}$ F above ambient. Wet-bulb depressions are $5\text{-}6^{\circ}$ F. As lumber dries, dry-bulb temperatures and wet-bulb depressions gradually increase until final dry-bulb temperatures reach about $30^{\circ}$ F

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2/ Ward, J.C., R.A. Hann, R.C. Baltes, and E.H. Bulgrin. 1972. Honeycomb and ring failure in bacterially infected red oak lumber. USDA For. Serv., Res. Pap. 165., For. Prod. Lab., Madison, Wis.

3/ Bois, P.J. 1977. Constructing and operating a small solar-heated lumber dryer. For. Prod. Util. Tech. Rep. No. 7., USDA For. Serv., State & Private Forestry, Madison, Wis.

above ambient with wet-bulb depressions of $24^{\circ}$ F. Two-inch-thick oak has been dried bright and defect-free to a moisture content of about 20 percent in 50 days of summer-drying weather. Final moisture contents of about 8 percent can be reached.

A forced-air dryer recirculates air and partially controls relative humidity by vent control. These are inexpensive structures with some heat and control systems. A two-step schedule now is used in a forced-air dryer operation at Princeton, W.Va., by the U.S. Forest Service[4/]. Transparent panels on the south roof of the dryer provide some solar-heating assistance.

Low-temperature kilns are inexpensive structures with dry-bulb and wet-bulb control systems. They may be operated at temperatures up to $120^{\circ}$ F. With additional insulation and heating capacity, these kilns will be similar to a conventional dry kiln. Schedules for both of these dryers (Princeton and "low-temperature kilns") have been developed and are shown in appendix A for drying heavy normal oak. During summer or if operation is adjacent to a warm kiln, it may not be possible to hold the recommended low dry-bulb and wet-bulb temperatures.

Controlled-air drying is generally in a building which will hold large volumes of green lumber (fig. 9). The objective is to begin drying with gentle and uninterrupted drying conditions. Some of these structures will hold 500,000 board feet. A constant temperature of 80-$85^{\circ}$ F is maintained, and relative humidities are controlled by venting. Air circulation is provided by ceiling-mounted fans providing about 100 feet per minute through the stickered packages. Drying times may be longer than in the forced-air dryer, but the gentle conditions will provide bright, defect-free lumber ready for the dry kiln.

Forced-air, low-temperature, and controlled-air dryers are designed primarily for removing moisture from a green to a well air-dried state (i.e., 20-30 percent moisture content); final moisture content is generally removed in a dry kiln in which fast drying and low moisture contents can be readily achieved.

Little, if any, information has been gathered to suggest how bacterially infected heavy oak should be dried in forced-air drying, low-temperature kilns, or controlled-air dryers. If the infected oak were sawn only into 4/4 lumber, predrying and low-temperature drying under mild conditions would probably reduce drying degrade.

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4/ Cuppett, D.G., and E.P. Craft. 1975. Low-temperature forced air-drying of Appalachian hardwoods. USDA For. Serv. Res. Pap. NE-328, Northeastern For. Exp. Sta., Upper Darby, Pa.

## Kiln-Drying Upland and Lowland Heavy Oaks

Upland oaks free of bacterial infection can be dried with kiln schedules recommended on page 120 of the Dry Kiln Operator's Manual[5/]. These schedules are shown in appendixes B and C. Grouping of 6/4 oak with 8/4 oak for schedule purposes is based on the experience of many kiln operators. The use of 180° F at 11 percent moisture content for 6/4 and 8/4 oak has been advocated by J.M. McMillen during Forest Service kiln-drying demonstrations at the Forest Products Laboratory; this procedure will save considerable kiln time when low final moisture contents are required. Heavy oaks kiln-dried in this manner from the green condition should be free of drying defects if kiln schedules are followed and if the dry kiln instruments and equipment are in proper calibration and working order. Because of long time kiln residence (up to 3 months for 8/4 green oak), heavy oaks are usually air-dried first. Again the quandry of possible degrade in the yard must be weighed against the long kiln times needed for green material.

Lowland oaks present a different drying problem. A recommendation for 4/4 schedule for both red and white lowland oak is given on page 121 of the Dry Kiln Operator's Manual[5/]. At present no kiln-drying schedule is available for drying heavy lowland red or white oak from the green condition without the possibility of heavy surface checking. Recommendations are to gently air-dry heavy lowland oaks to 25 percent moisture content, then kiln-dry. The kiln schedules for 4/4 southern lowland oaks and an irregular schedule for 6/4 and 8/4 lowland oaks, as developed by McMillen, are shown in appendix D.

McMillen and J.C. Ward of the Forest Products Laboratory suggest the kiln schedule shown in appendix E for bacterially infected 4/4 upland red oak. No kiln schedules are available for drying heavy bacterial infected oaks. All efforts to date have produced honeycomb and ring separation.

## Dehumidifier Drying-Energy Conservation

The reappearance and the current popularity of dehumidifier drying in the United States and Canada have been coincidental with oak-drying problems.

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5/ Rasmussen, E.F. 1961. Dry Kiln Operator's Manual, Agric. Handb. No. 188. USDA For. Serv., Washington, D.C.

The principle of operation of a dehumidifier dryer is that of a heat pump wherein the water evaporated from the wood is condensed on cool coils. This mode of operation is contrasted with conventional dryers wherein the evaporated water plus air must be vented from the kiln. Since no air enters the system (dehumidifier) and no venting is performed, the total energy consumption of this system is less than that found in existing kilns as now currently operated. The heat pump cycle is driven by electrical energy wherein all the input energy appears as heat at the condenser and fan motor. Additional electrical heat may be supplied as required for some drying schedules. The only heat demand of the closed system is heat loss by conduction through the walls of the dehumidifier dryer. Thus, to be effective dehumidifier dryers must be designed to reduce the heat loss through the walls of the chamber (R = 20-30, contrasted to R = 10 or less for conventional kilns). The economics of the system takes advantage of the reduced energy demand; however, the tradeoff is that per unit of energy, electric is far more costly than natural gas, wood waste, coal, or oil. Therefore, the first concern of any manufacturer must be the current electric rates, which of course vary considerably from one location to another in the United States. If retrofit of dehumidifiers to existing kilns is contemplated, the insulation of the dryer is a primary concern. If interrupted fuel supply is of paramount importance, then the extra cost of dehumidifier operation in high electric rate areas may be the lesser problem.

It should be made clear, however, that the mechanism of moisture movement in the wood remains the same. Maximum temperatures are usually in the range of $104^{\circ}$ F to $110^{\circ}$ F. There is no doubt that this system will dry wood. In Europe these dryers are usually small in capacity and are good for bringing somewhat refractory woods down to 10-12 percent moisture content. This is satisfactory for most uses in Europe.

In the United States and Canada, largely because of central heating and air-conditioning, recommended moisture content for indoor uses is 6-8 percent moisture content. In most wood species, the time required to reduce the moisture content from 12 percent to 6 or 8 percent is considerably longer than the same interval at higher moisture contents. Thus drying times become important in comparing dehumidification with conventional (about $180^{\circ}$ F maximum) or high temperature (above $212^{\circ}$ F) drying. Dehumidification drying offers no means of relieving drying stresses in lumber through a conditioning treatment after drying.

Stress relief is necessary if lumber is to be resawn or machined nonuniformly. Much heavy oak is reworked in this manner making stress relief essential. A conditioning treatment consists of subjecting the dried lumber to a high-temperature, high relative humidity condition for an appropriate length of time.

Dehumidification drying by nature of its low temperatures and small wet-bulb depressions during the critical stages of drying is well suited for drying heavy oak. Reports from manufacturers and users of such equipment report good results in drying oak (fig. 10). One manufacturer has coupled a dehumidifier drying unit with a conventional dry kiln. The dehumidifier portion of the dryer is used to remove moisture from the green condition to a moisture content of about 25 percent. At this point the conventional drying schedule for oak is resumed and the oak dried to the final moisture content (figs. 11 and 12). The charge can then be equalized for uniform moisture content and conditioned to relieve drying stresses. Total drying times are less than dehumidifier drying alone; drying stresses are relieved, and the oak is reportedly dried with a minimum of degrade.

No reports of drying bacterially infected material have been noted but by nature of low initial drying temperatures, dehumidifier drying should be helpful in reducing degrade if handling this type of material.

## Solving the Drying Problem - Laminating

Because drying degrade and prohibitively long drying times are associated with heavy oak, the author believes heavy kiln-dried stock should be prepared by laminating thinner material. Thinner lumber dries with less degrade, and drying times both in air drying and kiln drying are considerably shorter. Less degrade develops because steep moisture gradients and high stress development are avoided. Drying times for 1-inch oak will be 1/3 to 1/4 those required for 2-inch oak with considerable savings in energy.

To further benefit the manufacturer, synthetic glues available today provide colored or uncolored glue lines with high strength and durability.

The buying public is laregely unable to distinguish between solid wood and well laminated wood. Even if laminations are detectable, laminated wood is usually pleasing to the eye. If problems in handling and drying heavy oak continue, it is logical to consider laminating as a means of increasing yields and lowering energy and other production costs.

## Storage of Heavy Oak

After lumber is kiln-dried, it is generally placed in some type of storage awaiting shipment or use. After kiln drying, lumber may be held in a cooling shed; these sheds are sometimes heated to maintain a low wood equilibrium moisture content (EMC) condition.

If kiln-dried lumber is stored in a heated or relative humidity controlled closed shed, it may be kept for months. Thus the lumber is held at the desired moisture content. Lumber so stored may be left on stickers or solid piled.

The amount of heat necessary to maintain an EMC condition can be determined from figure 13. In the example, assume a 50$^{\circ}$ F ambient temperature and a relative humidity of 80 percent. This set of conditions produces an EMC of about 16 percent, too high for kiln-dried lumber. By raising the dry-bulb temperature to 65$^{\circ}$ F, a 9-percent EMC is attained; by raising the dry-bulb to 75$^{\circ}$ F, a 7-percent EMC condition is attained.

Another option for the operator is to control EMC by regulating relative humidity. Note that the relative humidity lines in figure 13 are almost parallel to the EMC lines. Thus by holding about 32-37 percent relative humidity in the storage shed, an EMC of 7 percent is maintained.

Relative humidity can be controlled by dehumidifier units and fans if outdoor conditions are humid and by steam or water-atomizing systems if ambient conditions are too dry.

Kiln-dried lumber stored in an unheated closed shed will tend to absorb some moisture because the average moisture content of the kiln-dried lumber is usually lower than the EMC of the prevailing ambient air. For increased protection from moisture changes, an unheated, closed shed should have a paved floor. Kiln-dried lumber should not be stored in this manner for more than a few months and should first be unstickered and solid piled. If kiln-dried lumber stored in this manner is wrapped in a moisture-resistant paper or film, additional protection is achieved against moisture regain.

Storage conditions in a woodworking or furniture plant also require attention since lumber may be in process for several days or longer. This is a form of lumber storage, and relative humidity control is essential during winter months when cold outdoor air is heated to the indoor comfort level. In this example, assume outdoor winter air is at 20$^{\circ}$ F and 75 percent relative humidity, a common winter condition in the northern states. From figure 13, it can be seen that this produces a 15-percent EMC condition. However, when this air is heated to 70$^{\circ}$ F indoors and no further moisture is added, the EMC in the plant drops to less than 3 percent. This warm, extremely dry air is responsible for panel warpage, end splits, and poor gluing conditions in a furniture plant. Proper humidification as suggested or year-round air-conditioning can maintain the desired EMC condition for wood processing.

Kiln-dried lumber should never be stored in open unheated sheds except for short periods, or moisture changes in the lumber will occur. Exceptions to this are during sunny seasons of the dry southwestern states of Arizona, New Mexico, and California (southern) where outdoor EMC conditions are usually at or near kiln-drying moisture conditions.

In summary, points to remember are the following:

Kiln-dried lumber should be stored in a heated cooling shed if the lumber is left on stickers pending transport to a rough mill or cut-up plant.

If lumber is bulked for storage outdoors, protection from the weather is essential, and the storage period must be short.

Bulked indoor storage should be in an EMC-controlled storage area.

Figure 1.--Inexpensive double-entry shed of pole-wood truss-type construction for drying heavy, refractory hardwoods.

Figure 2.--Air-drying hardwood lumber by double-entry metal shed system.

Figure 3.--Single-entry drying shed with louvered back wall for restricted airflow is excellent for air-drying heavy, refractory hardwoods.

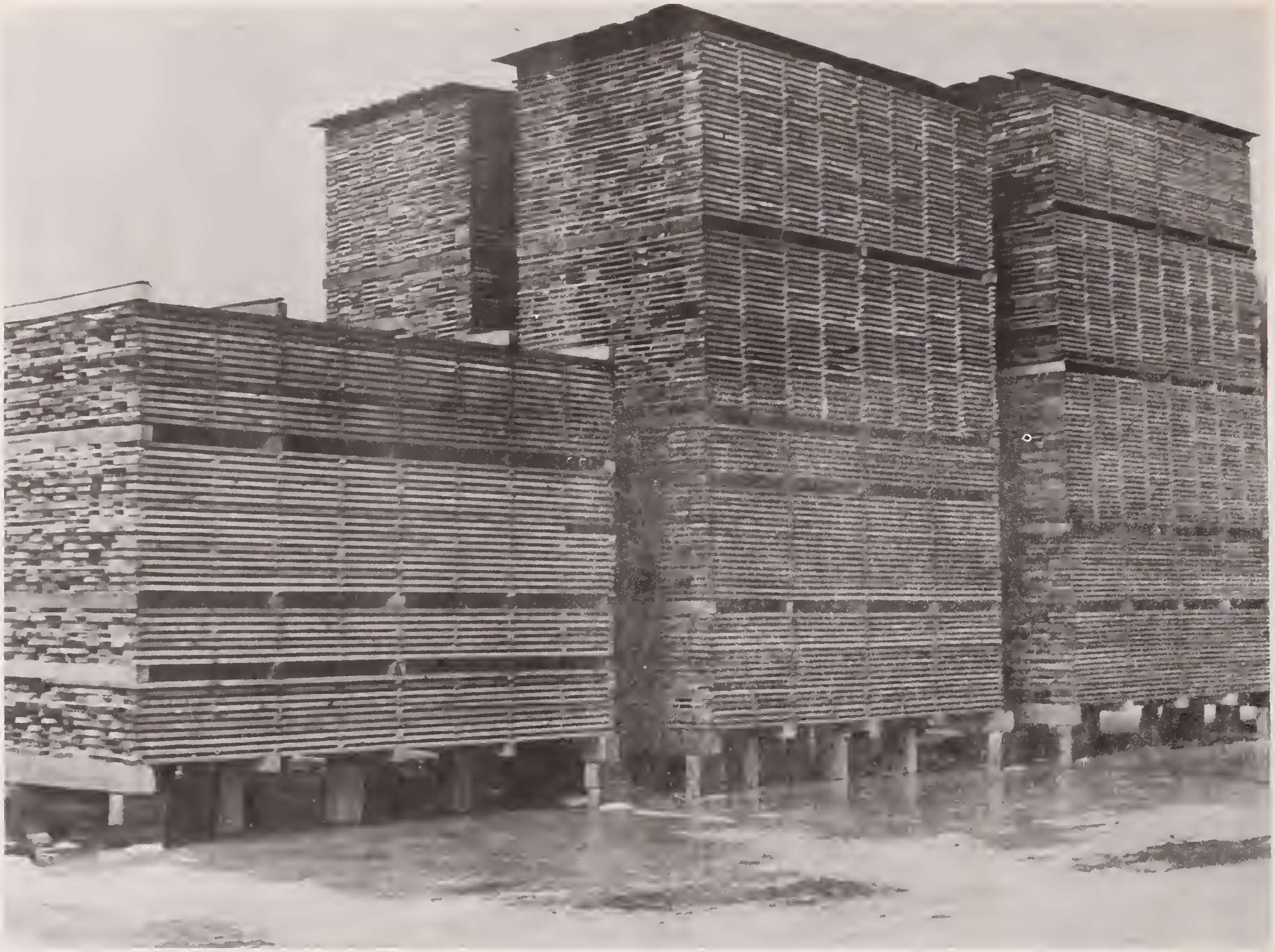

Figure 4.--Wooden roof covers give some protection to refractory drying species.

Figure 5.--Corrugated metal roof covers with spring steel clamps hold roof in place on oak drying yard in southern United States.

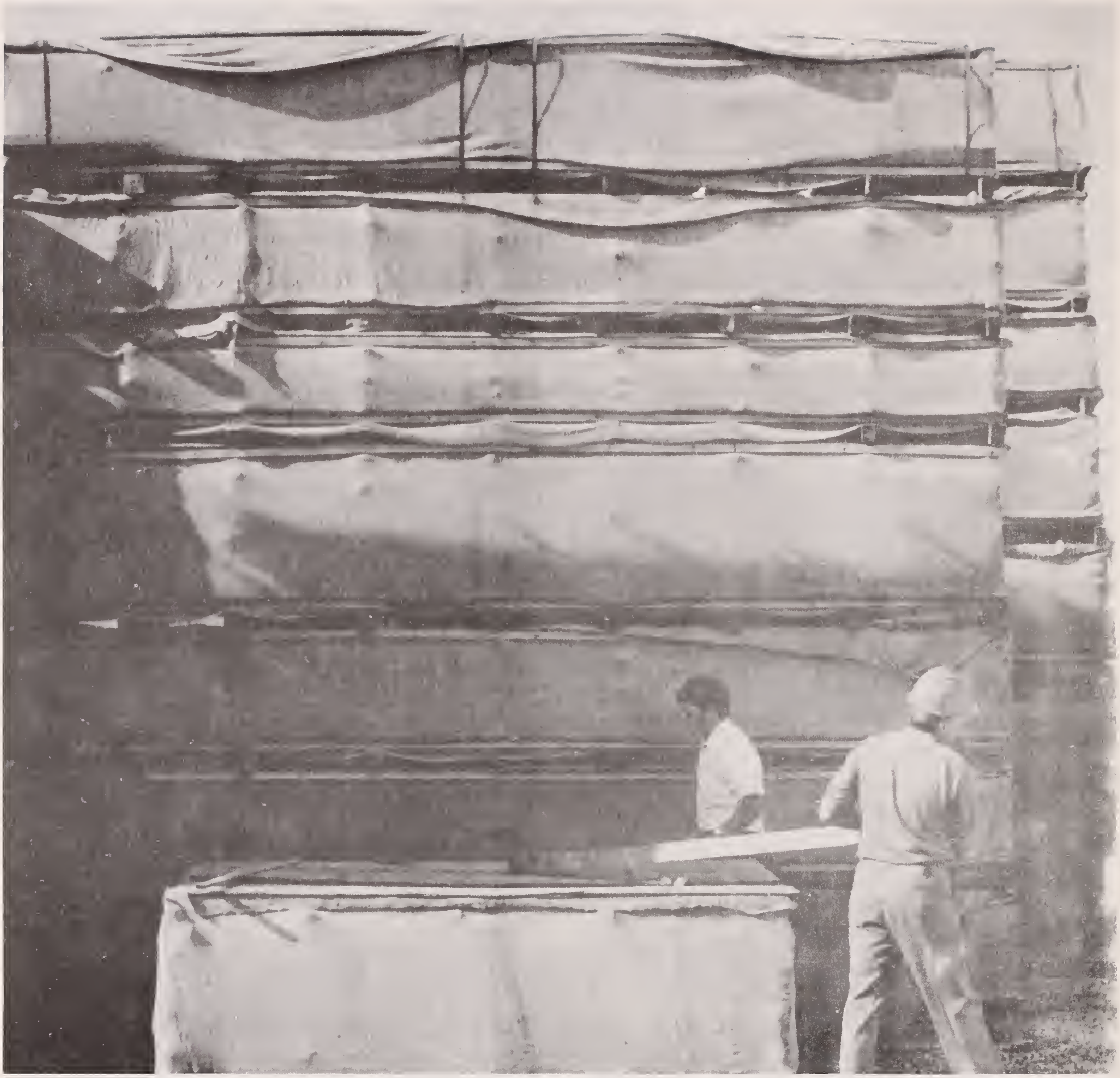

Figure 6.--Burlap-wrapped, end-coated 8/4 oak with plywood roof cover on air-drying yard in eastern United States.

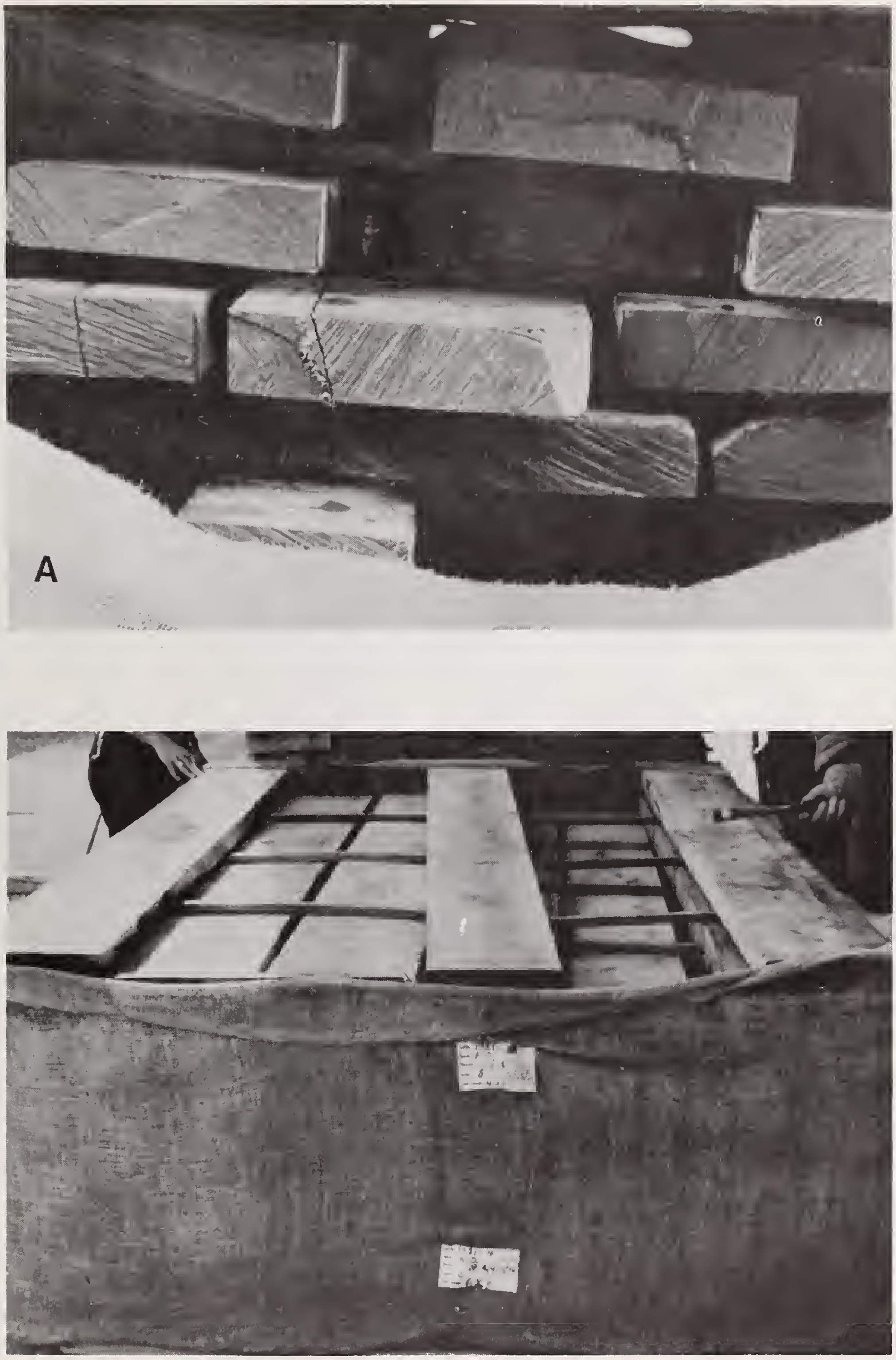


Figure 7A and B.--Burlap-covered heavy oak reveals little end checking or surface checking after air-drying on yard in eastern United States.

Figure 8.--East side of solar lumber dryer for drying small amounts of lumber shows principal loading and unloading door and small access to collector area.

Figure 9.--Commercially used controlled-air drying structure for drying green oak.

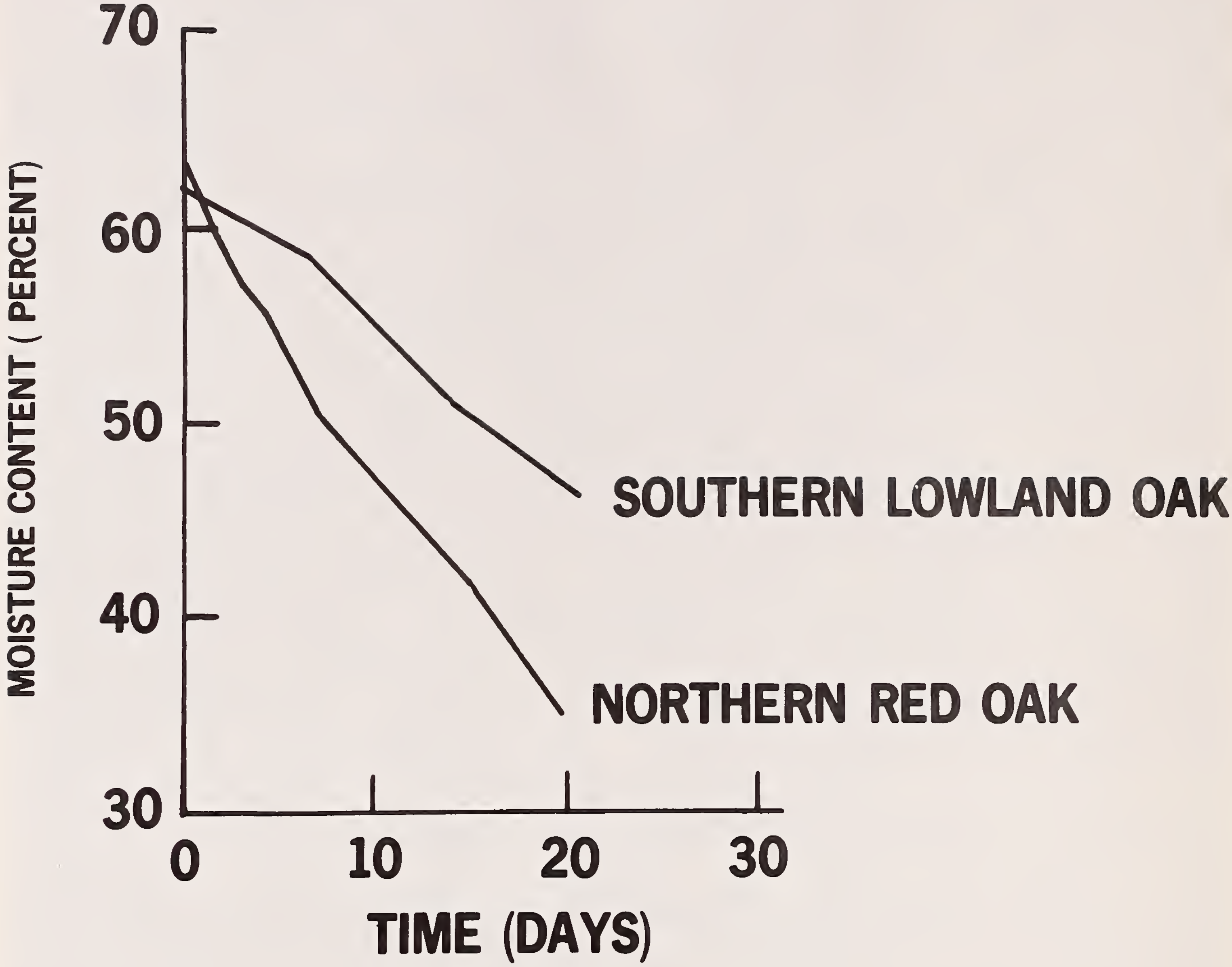


Figure 10.--Comparison of typical drying rate in dehumidification drying between 8/4 Northern Upland red oak and 8/4 Southern Lowland red oak.

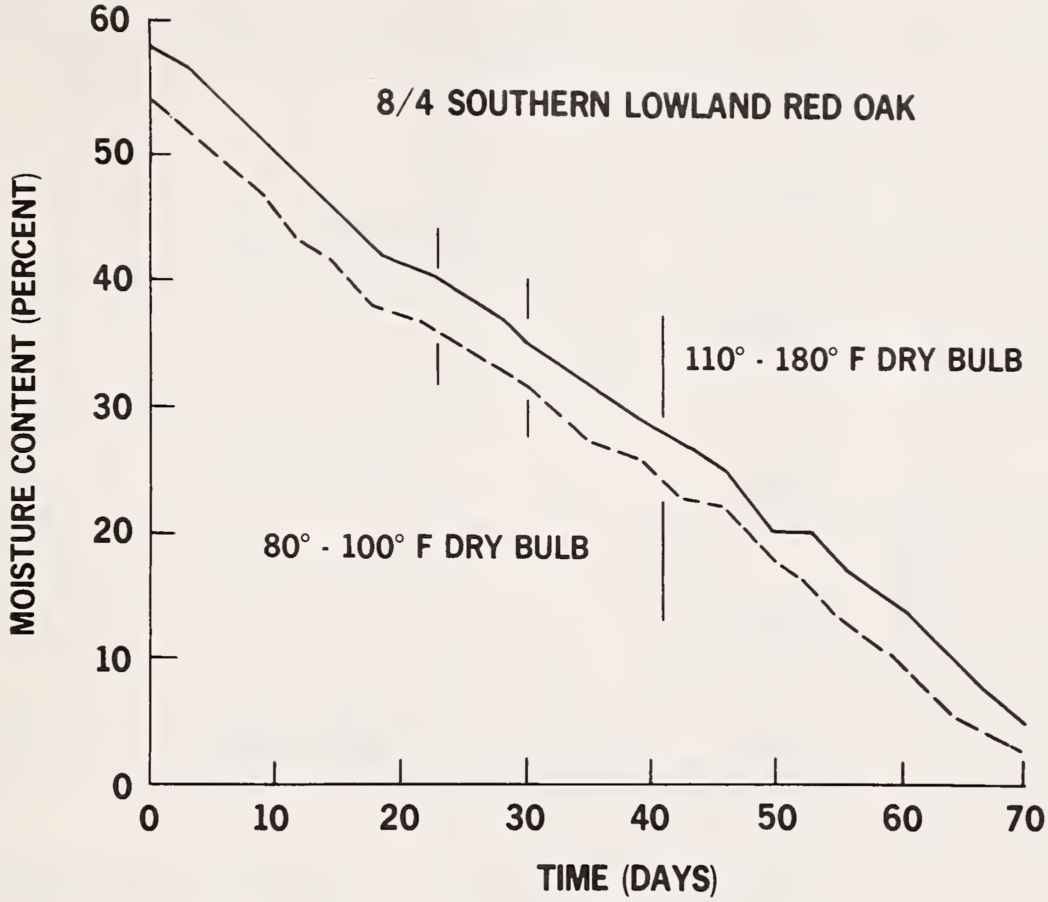


Figure 11.--Drying rates of two charges of 8/4 Southern Lowland red oak with combination of dehumidification drying followed by conventional kiln-drying.

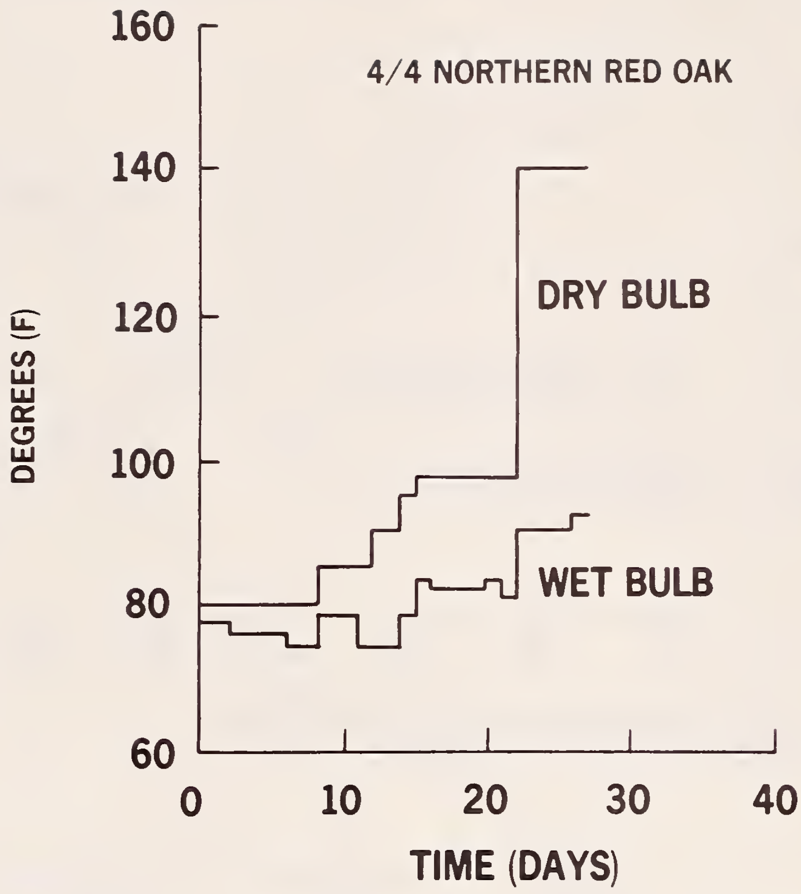


Figure 12.--Dry bulb-wet bulb schedule used in combination dehumidification-conventional drying of 4/4 Northern red oak.

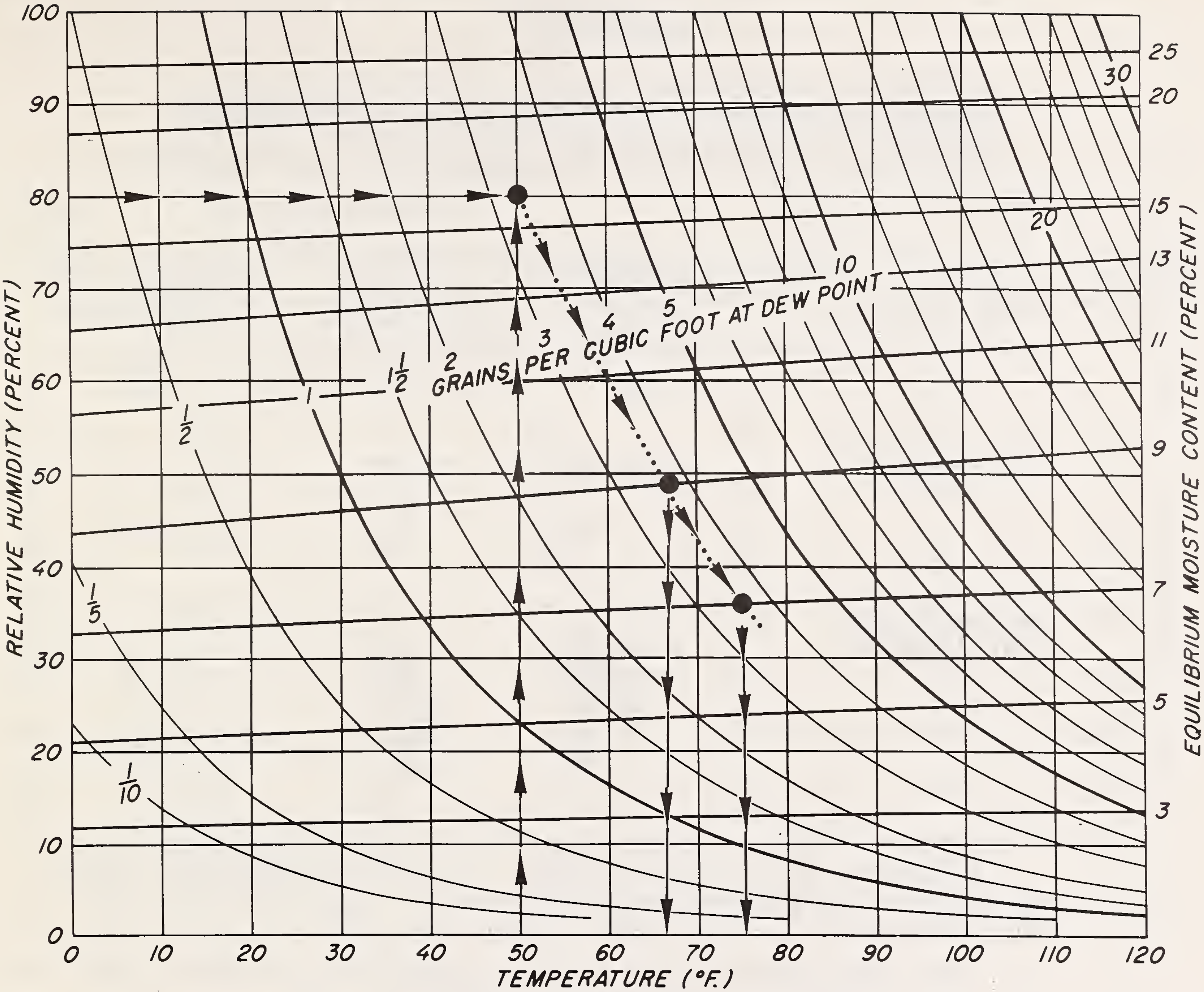


Figure 13.--Relationships between relative humidity, absolute humidity, temperature, and equilibrium moisture content.

Appendix A

Princeton Forced-Air Drying Schedule and Low-Temperature Kiln-Drying Schedule for Heavy (thick) Red and White Oaks

| Drying Schedule | Moisture content at start | Dry-bulb temperature | Wet-bulb Depression |
|---|---|---|---|
| | Pct | °F | °F |
| Princeton forced air drying 1/ | above 45 | 70-80 | 3 |
| | 40 | 90 | 2/ |
| Low-temperature kiln drying 3/ | above 60 | 90 | 2 |
| | 50-60 | 95 | 2 |
| | 40-45 | 100 | 5 |
| | 35 | 100 | 10 |
| | 30 | 100 | 15 |

1/Cuppett, D.G., and E.P. Craft. 1975. Low temperature forced air drying of Appalachian hardwoods. USDA For. Serv. Res. Pap. NE-328, Northeastern For. Exp. Sta., Upper Darby, Pa.

Air velocities 250-350 feet per minute maximum; for check-prone oaks, operate fans at night only (12 h).

2/No control of wet-bulb depression.

3/Contact R.G. Potter, Potter Lumber Co., Allegany, N. Y.

Air velocities of 350-450 feet per minute.

Appendix B

Kiln Schedules for Red Oak--Northern and Upland[1/]

| Moisture content at start of step | 4/4, 5/4 (T4-D2)[2/] | | | 6/4, 8/4 (T3 - D1)[2/] | | |
|---|---|---|---|---|---|---|
| | Dry-bulb temperature | Wet-bulb depression | Wet-bulb temperature | Dry-bulb temperature | Wet-bulb depression | Wet-bulb temperature |
| Pct | | °F | | | °F | |
| Above 50 | 110 | 4 | 106 | 110 | 3 | 107 |
| 50 | 110 | 5 | 105 | 110 | 4 | 106 |
| 40 | 110 | 8 | 102 | 110 | 6 | 104 |
| 35 | 110 | 14 | 96 | 110 | 10 | 100 |
| 30 | 120 | 30 | 90 | 120 | 25 | 95 |
| 25 | 130 | 40 | 90 | 130 | 40 | 90 |
| 20 | 140 | 45 | 95 | 140 | 45 | 95 |
| 15 | 180 | 50 | 130 | 160 | 50 | 110 |
| 11 | | | | 180 | 50 | 130 |
| Equalize[3/] | 180 | 35 | 145 | 180 | 35 | 145 |
| Condition | 180 | 10 | 170 | 180 | 10 | 170 |

1/ For all oak species, 6/4 stock usually is dried by the 8/4 schedule.

2/ Code number designation from: E.F. Rasmussen, 1961. Dry Kiln Operator's Manual. Agric. Handb. No. 188. USDA For. Serv., Washington, D.C.

3/ For final target moisture content of 7 percent.

## Appendix C

### Kiln Schedules for White Oak--Northern and Upland[1/]

| Moisture content at start of step | 4/4, 5/4 (T4-C2)[2/] | | | 6/4, 8/4 (T3-C1)[2/] | | |
|---|---|---|---|---|---|---|
| | Dry-bulb temperature | Wet-bulb depression | Wet-bulb temperature | Dry bulb temperature | Wet-bulb depression | Wet-bulb temperature |
| Pct | °F | | | °F | | |
| Above 40 | 110 | 4 | 106 | 110 | 4 | 107 |
| 40 | 110 | 5 | 105 | 110 | 4 | 106 |
| 35 | 110 | 8 | 102 | 110 | 6 | 104 |
| 30 | 120 | 14 | 106 | 120 | 10 | 110 |
| 25 | 130 | 30 | 100 | 130 | 25 | 105 |
| 20 | 140 | 45 | 95 | 140 | 40 | 100 |
| 15 | 180 | 50 | 130 | 160 | 50 | 110 |
| 11 | | | | 180 | 50 | 130 |
| Equalize[3/] | 180 | 35 | 145 | 180 | 35 | 145 |
| Condition | 180 | 10 | 170 | 180 | 10 | 170 |

1/ For all oak species, 6/4 stock usually is dried by the 8/4 schedule.

2/ Code number designation from: E.F. Rasmussen, 1961. Dry Kiln Operator's Manual. Agric. Handb. No. 188. USDA For. Serv., Washington, D.C.

3/ For final target moisture content of 7 percent.

Appendix D

Kiln Schedules for Red and White Oak--Southern Lowland[1/]

| Moisture content at start of step | 4/4, 5/4 (T2-C1)[2/] | | | 6/4, 8/7 (irregular) | | |
|---|---|---|---|---|---|---|
| | Dry-bulb temperature | Wet-bulb depression | Wet-bulb temperature | Dry-bulb temperature | Wet-bulb depression | Wet-bulb temperature |
| Pct | | °F | | | °F | |
| Above 40 | 100 | 3 | 97 | | | |
| 40 | 100 | 4 | 96 | (Air-dry to 25 pct MC) | | |
| 35 | 100 | 6 | 94 | | | |
| 30 | 110 | 10 | 100 | 105 | 8 | 97 |
| 25 | 120 | 25 | 95 | 110 | 11 | 99 |
| 20 | 130 | 40 | 90 | 120 | 15 | 105 |
| 15 | 150 | 45 | 105 | 130 | 30 | 100 |
| 11 | 160 | 50 | 110 | 160 | 50 | 130 |
| Equalize[3/] | 180 | 35 | 145 | 180 | 50 | 130 |
| Condition | 180 | 10 | 170 | 180 | 10 | 170 |

1/ For all oak species, 6/4 stock usually is dried by the 8/4 schedule.

2/ Code number designation from: E.F. Rasmussen, 1961. Dry Kiln Operator's Manual. Agric. Handb. No. 188. USDA For. Serv., Washington, D.C.

3/ For final target moisture content of 7 percent.

## Appendix E

### Upland Red Oak, Bacterially Infected 4/4 Schedule for Minimizing Honeycomb and Degrade

| Moisture content at start of step | Dry-bulb temperature 1/ | Wet-bulb depression | Wet-bulb temperature 1/ |
|---|---|---|---|
| Pct | $^{o}F$ | | |
| Above 60 | 105 | 3 | 2/ 102 |
| 60 | 105 | 3 | 3/ 102 |
| 50 | 105 | 4 | 101 |
| 45 | 105 | 6 | 99 |
| 40 | 105 | 10 | 95 |
| 35 | 110 | 15 | 95 |
| 30 | 115 | 30 | 85 |
| 25 | 120 | 35 | 85 |
| 20 | 130 | 42 | 88 |
| 15 | 150 | 50 | 100 |
| 11 | 170 | 50 | 120 |
| Equalize 4/ | 170 | 36 | 134 |
| Condition | 180 | 10 | 170 |

1/ For air-dried stock at 25 percent or lower moisture content, start dry-bulb temperature in accordance with above schedule, but use $10^{o}$ F wet-bulb depression 16 to 24 hours before going to new wet-bulb setting, depending on moisture content of controlling samp.es at that time.

2/ Run fans at night only (12 h).

3/ Full-time fan operation.

4/ For final target moisture content of 7 percent.



☆ U.S. GOVERNMENT PRINTING OFFICE: 1977—750-027/73